Developing Algorithm Components for GPM Snowfall Retrievals

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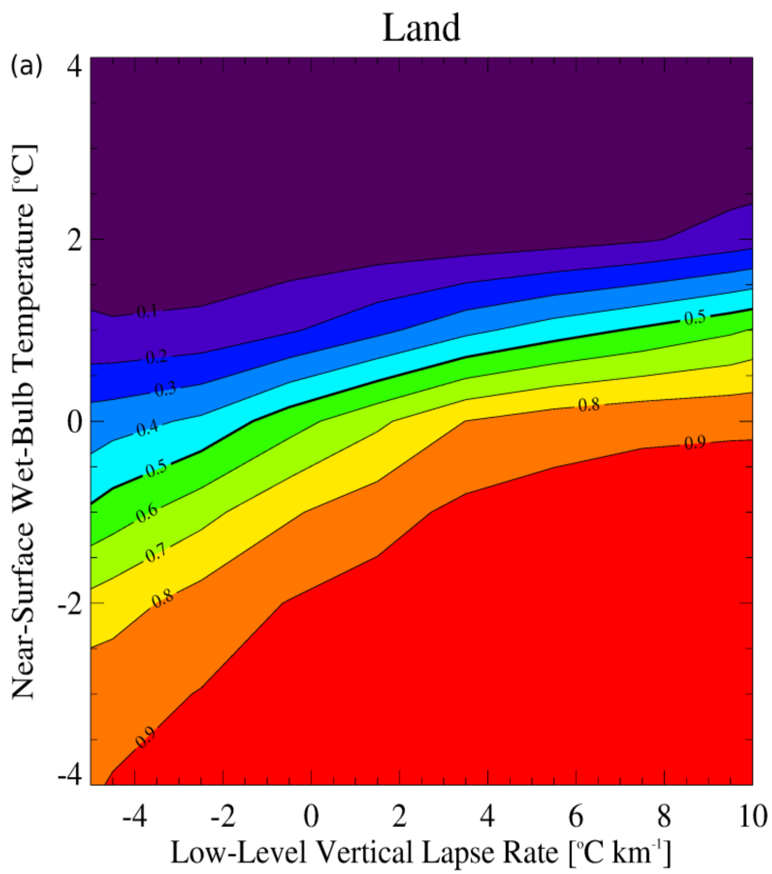
Research Progress

- Snow-Rain Separation Scheme
  - Inclusion of lapse rate correction
  - Equation version available – remove "bumpy points" in lookup tables
- Nonspherical Particle Scattering Tables
  - Inclusion of aggregates
  - Application to triple-F radar ice signatures → convective vs. stratiform
- Radar-Guided High-Freq MW Radiometer Snowfall algorithm
  - DPR+CloudSat → Quality of training data
  - For GMI
  - For MHS → Channel selection
- Study on 1D-VAR Optimized Database for Over-Ocean Snowfall
  - For GMI → Factors that contribute observed-simulated TB difference

Separating Snow and Rain Conditions Using Environmental Information

Goal: Find an optimal way to separate snow from rain pixels so that proper algorithms can be applied.

Snow-Rain Separation



Data Used:
Land: NCEP ADP Operational Global Surface Observations, 1997-2007
Ocean: International Comprehensive Ocean-Atmosphere Data Set (ICOADS), 1995-2007
Upper Air: Integrated Global Radiosonde Archive (IGRA)

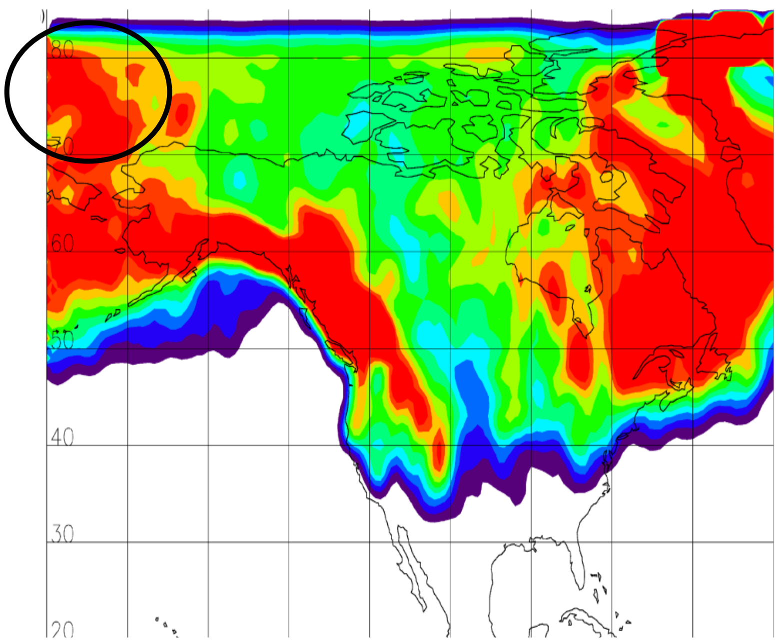
Sensitive Variables

- **Air temperature (2 m)**
- **Humidity (2 m)**
- **Low-level (0 - 500 m) lapse rate**
- **Surface skin temperature**
- **Land or ocean**

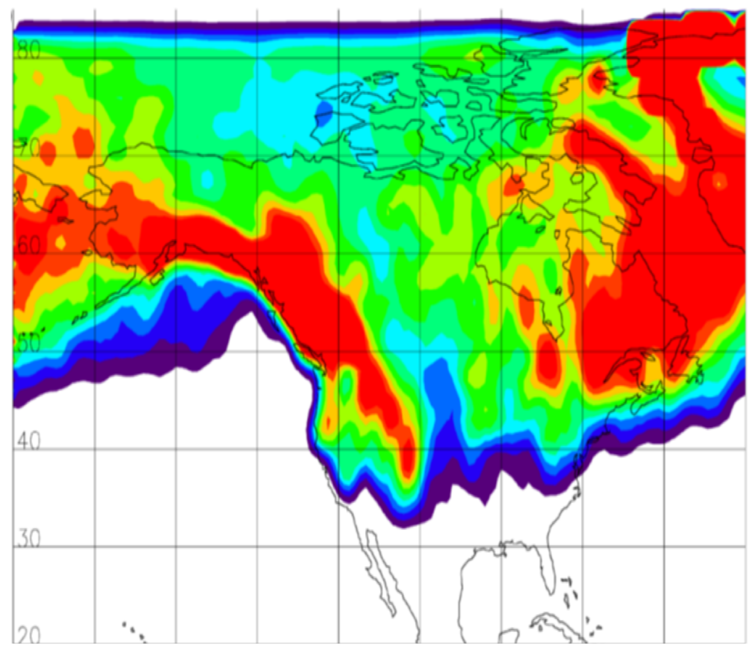
Look-Up-Table Version: Sims & Liu 2015 , Equation Version: Yin & Liu 2018

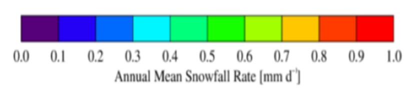
does it matter?

When using simple 2°C threshold

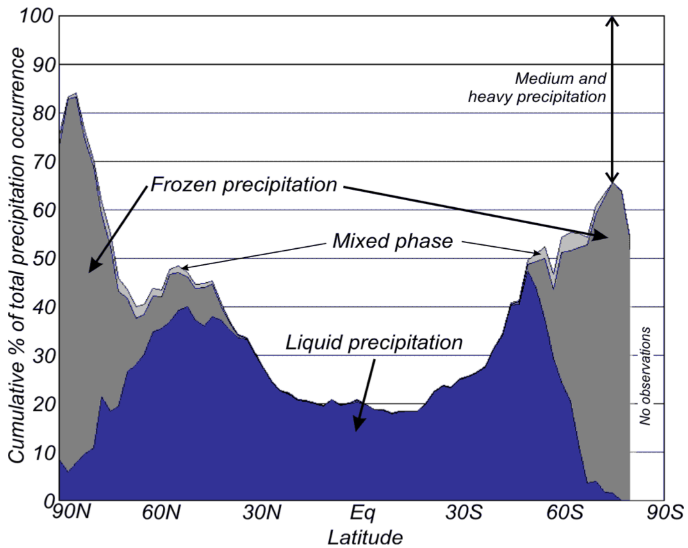


When using all-parameter threshold



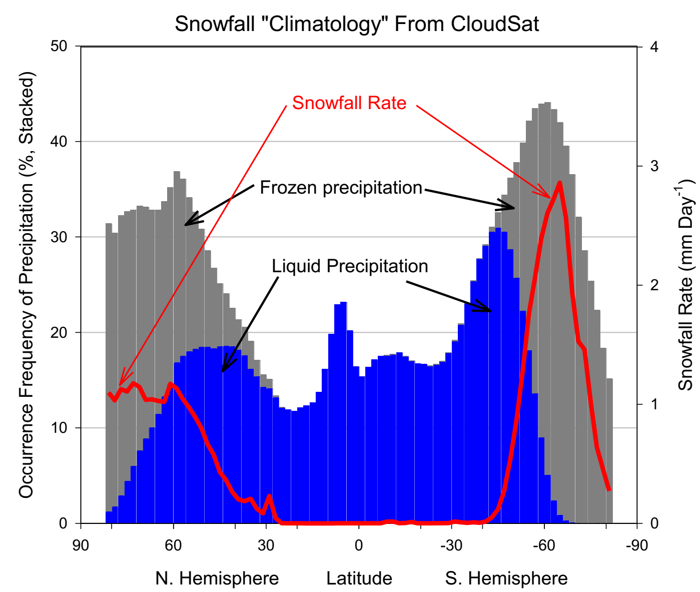


When Apply to CloudSat



Mean Zonal occurrence of oceanic light precipitation (<1.0 mm/h) as a percentage of total precipitation occurrence, derived from COADS ship-borne data (1958-1991).

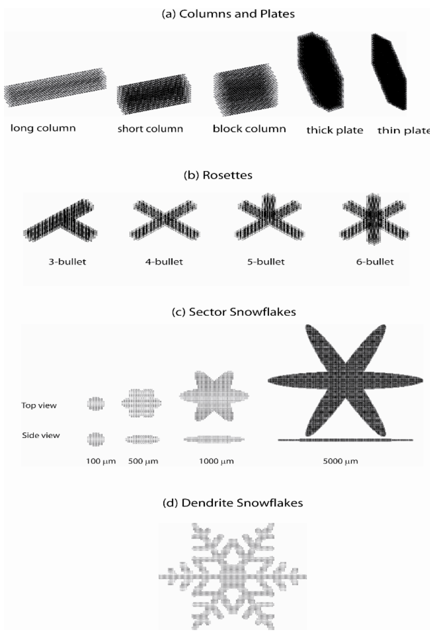
Occurrence Frequency and Snowfall rate, averaged over all observations of CloudSat from 2006 to 2010.

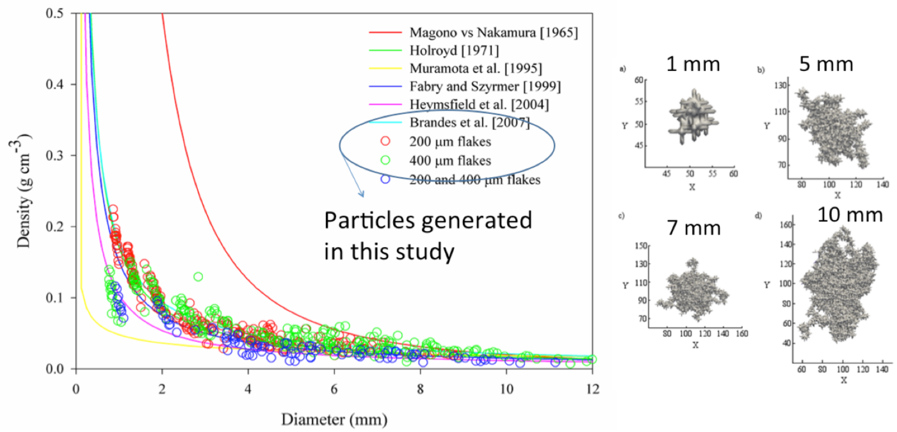


Scattering Database for Nonspherical Ice Particles

Goal: 1. improve physical retrievals
2. understand observed radiative signatures

Scattering Database for Nonspherical Snowflakes



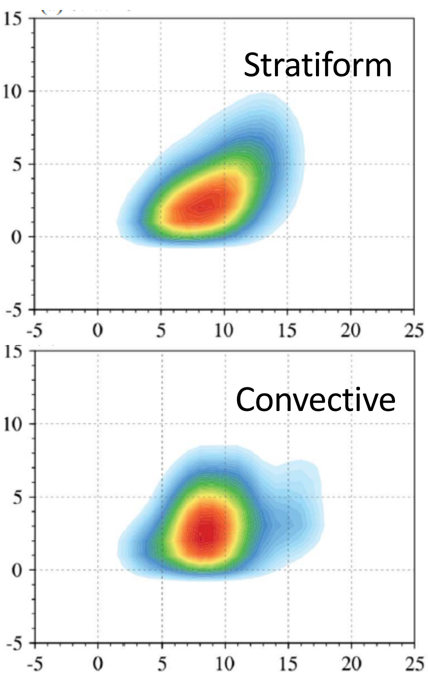


Crystal type particles (Liu, 2008)

Aggregate snowflakes: rounded, oblate and prolate (Nowell et al., 2013; Honeyager et al. 2015)

Difference in Ice Microphysics Between Convective and Stratiform Clouds

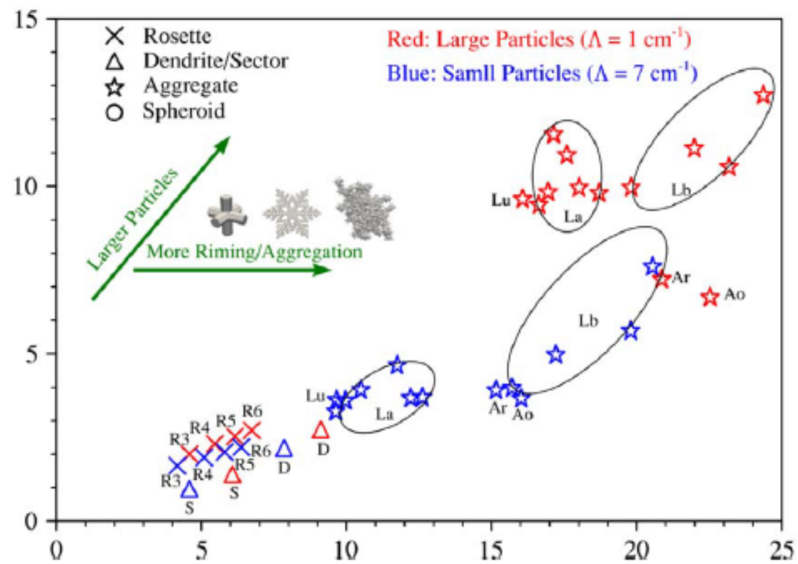
Observed Frequency of Occurrence



Ku/Ka Reflectivity Ratio: $10\log(\frac{Z_{Ku}}{Z_{Ka}})$

Ku/Kw Reflectivity Ratio: $10\log(\frac{Z_{Ku}}{Z_{Kw}})$

Simulated Triple-Frequency Signature based on multiple scattering scattering tables



Leinonen & Szyrmer 2015 particles:
Lu: unrimed
La: lightly rimed
Lb: Heavily rimed

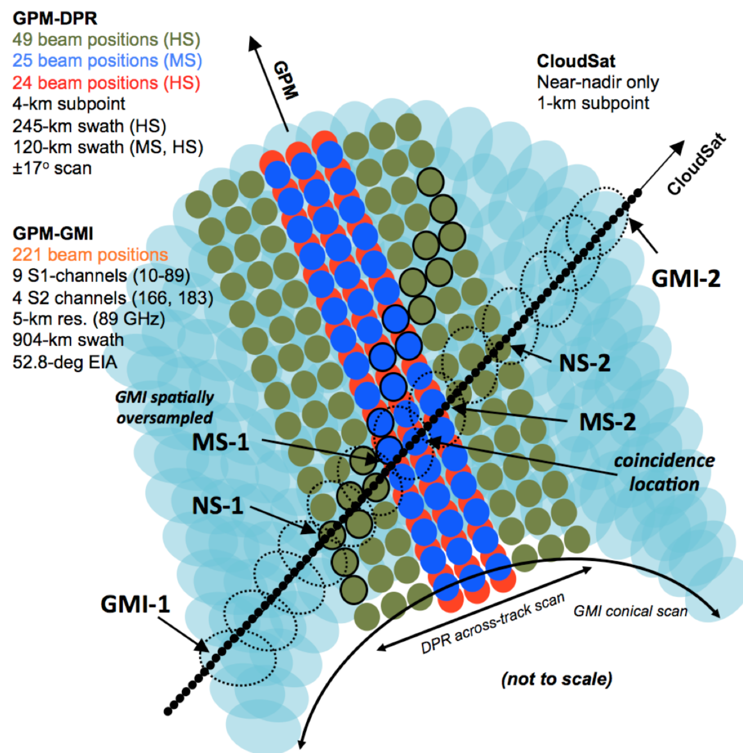
(Yin, Liu and Turk, 2017)

Radar-guided high-freq microwave radiometer snowfall retrievals

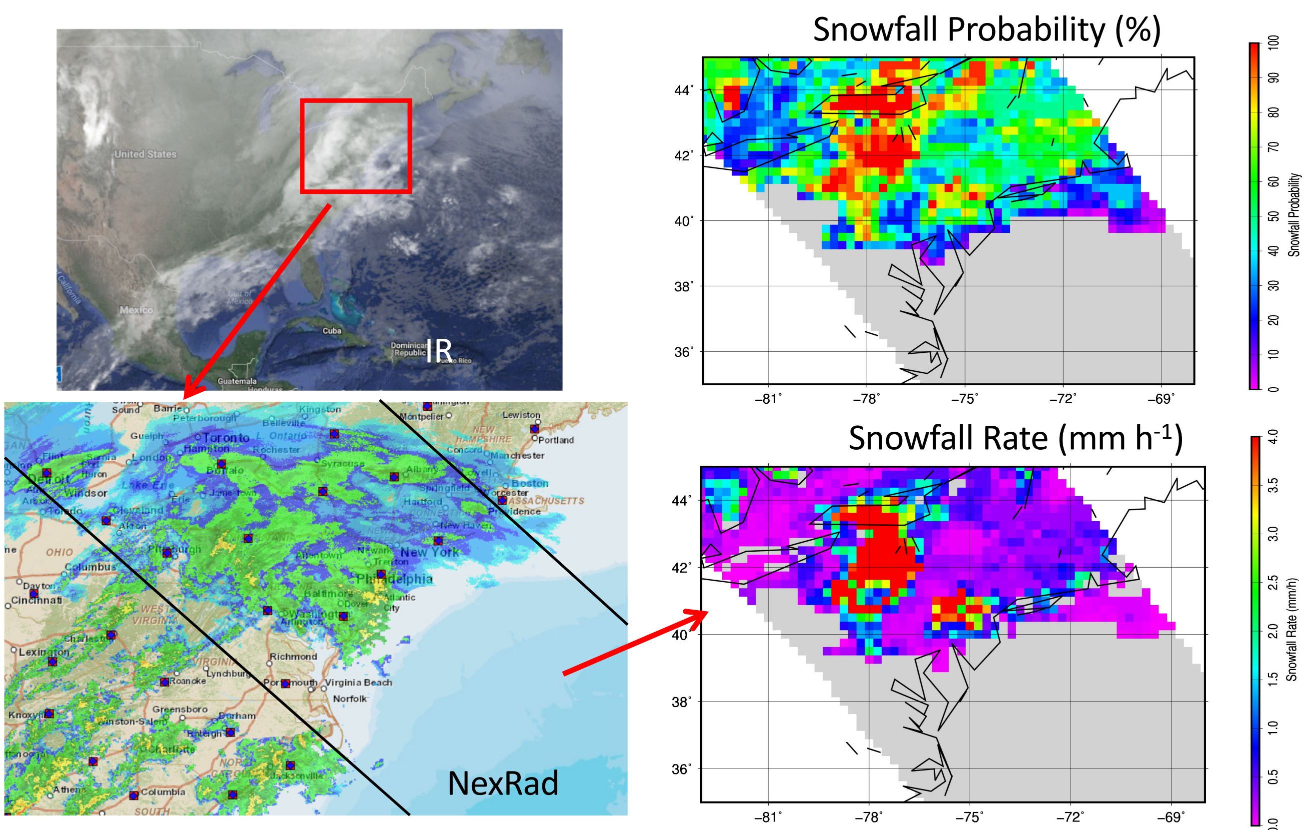
1. Important channels for snowfall retrievals
2. The importance of using both CloudS CPR AND DPR

2B-CSATGPM – J. Turk

- CloudSat – GPM within +/- 15 min nearest-neighbor
- Many other passive microwave sensors are also collocated
- Time period: 2014.03 – present

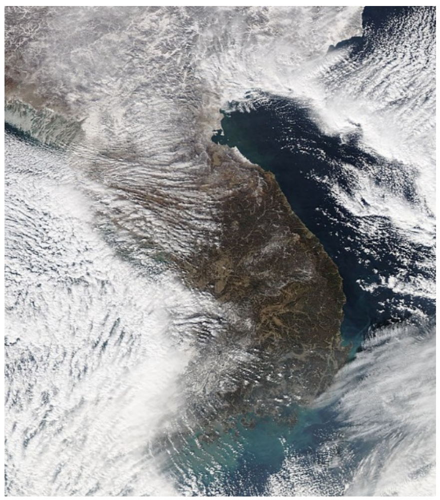


Feb. 2, 2015 North American Blizzard

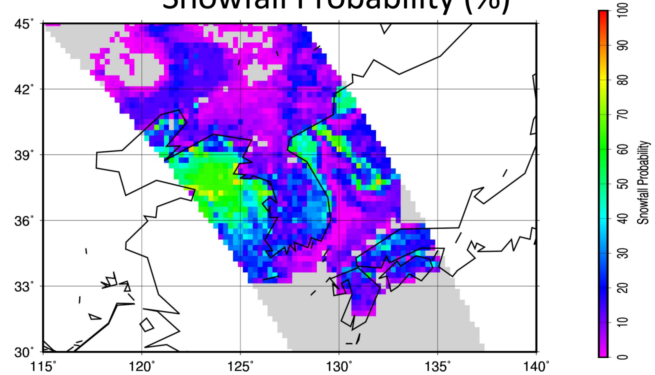


Jan 23, 2016 Cold Air Outbreak

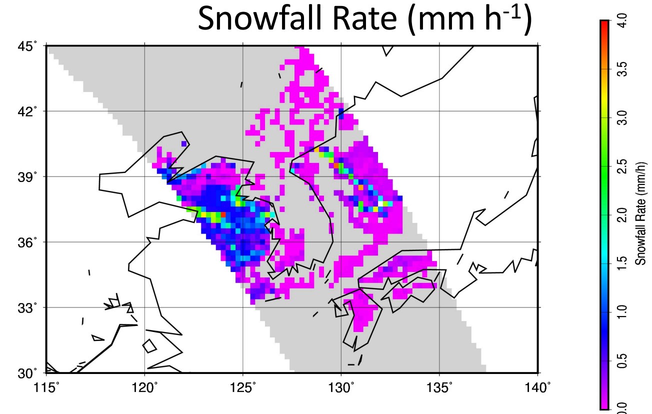
Aqua MODIS true color image for a snowfall case on 23 Jan 2016 (from *NASA/EOSDIS*)



Snowfall Probability (%)

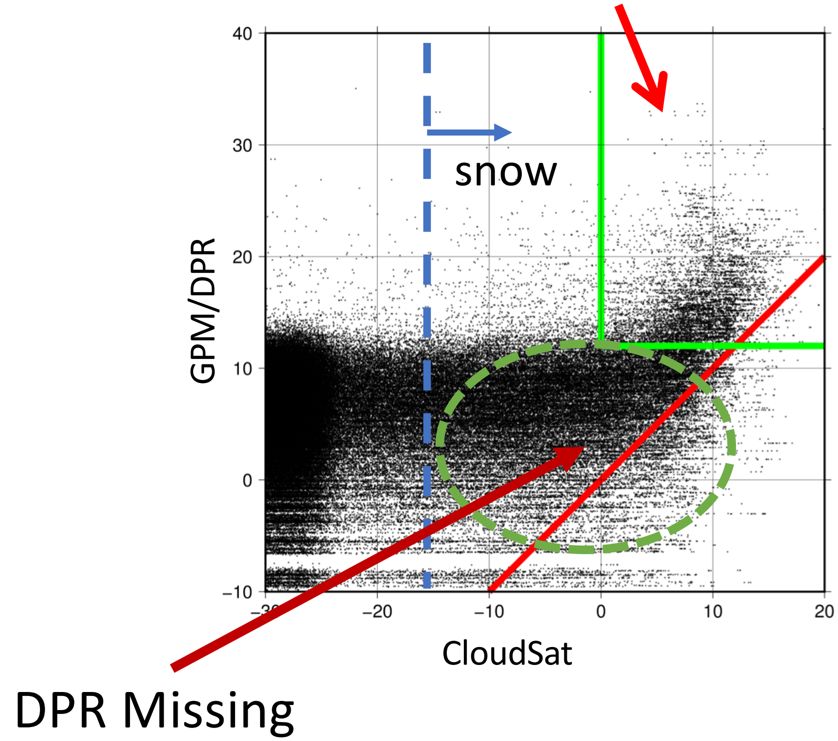


Snowfall Rate (mm h^{-1})

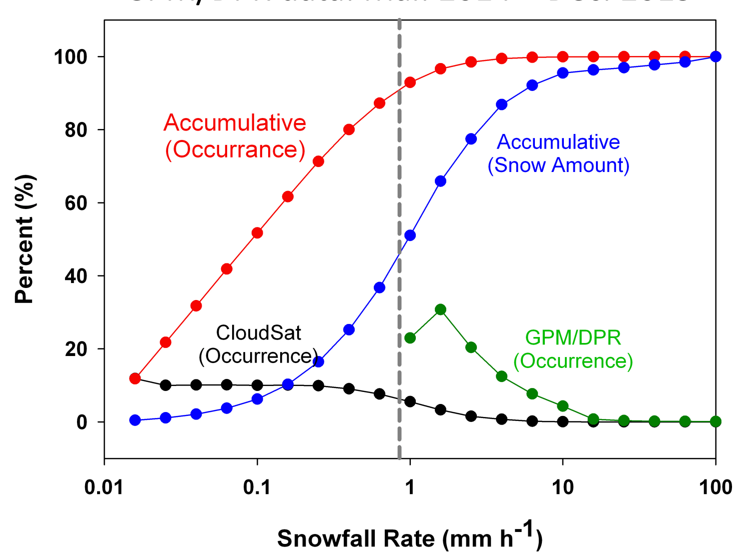


Use combined CloudSat/CPR and GPM/DPR as “truth”

CloudSat Underestimates



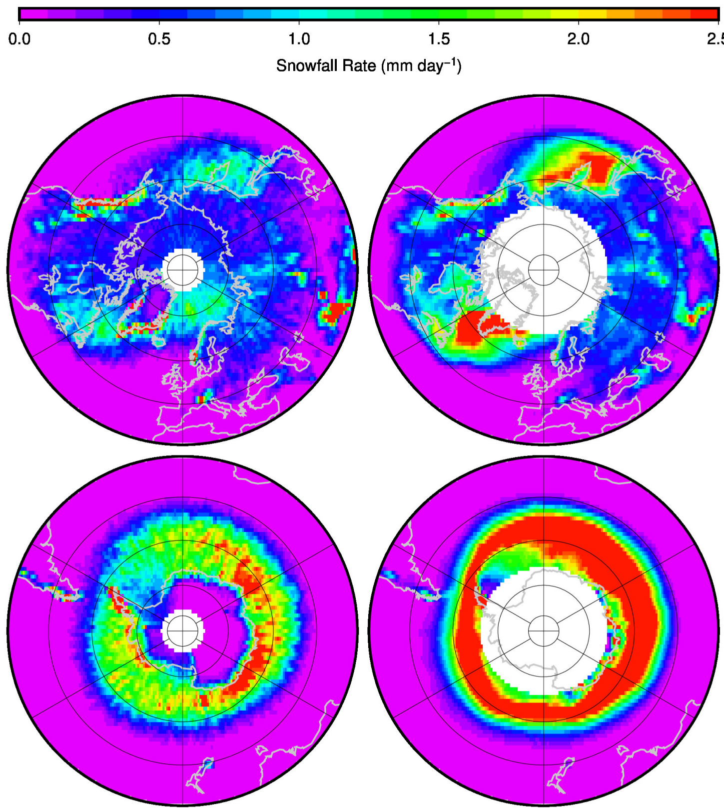
Based on collocated CloudSat/CPR - GPM/DPR data: Mar. 2014 – Dec. 2015



DPR misses ~50% of snowfall volume

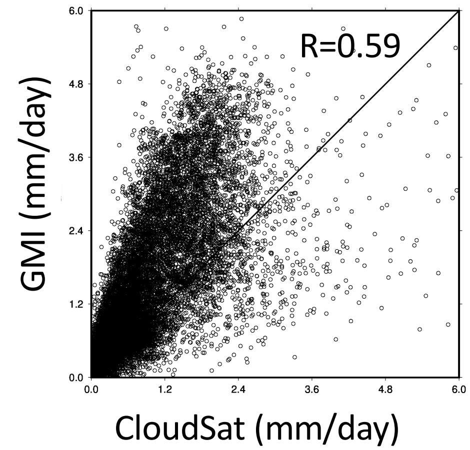
Use 2B-CSATGPM dataset of Turk (2015)

CloudSat vs. GMI - Global

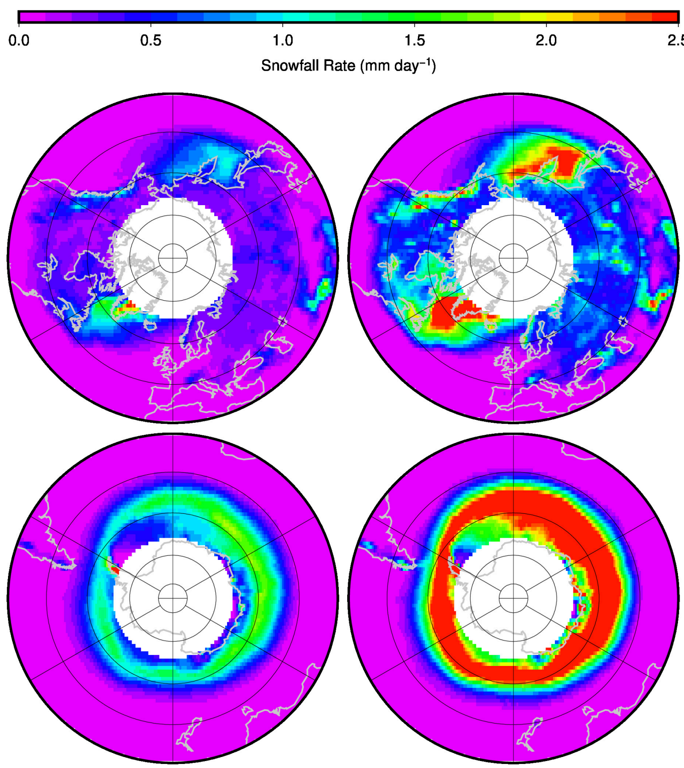


CloudSat Retrieval
(4 years average)

GMI Retrieval
(4 years average)
(18 – 183 GHz Channels)

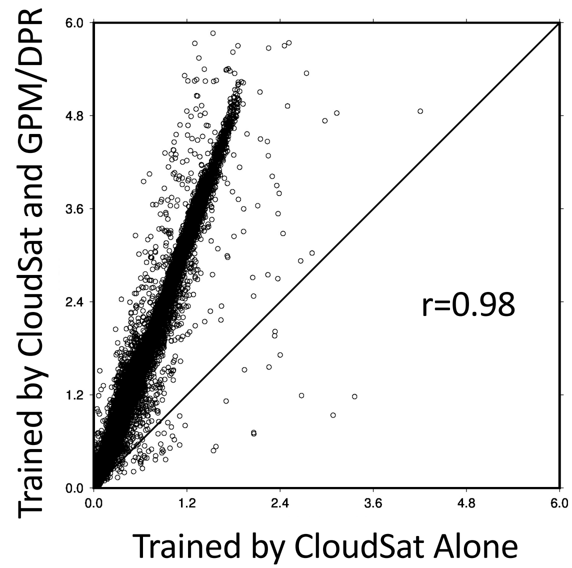


Train Retrieval Algorithm
Using CloudSat Alone vs. CloudSat+DPR

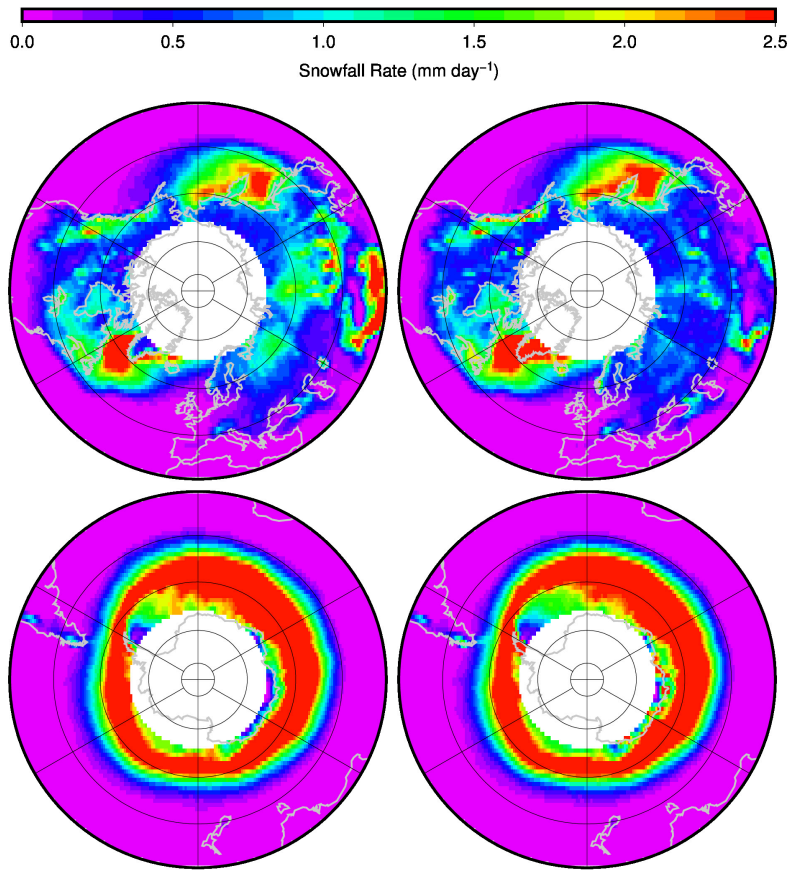


Train by
CloudSat Alone

Train by
CloudSat + DPR

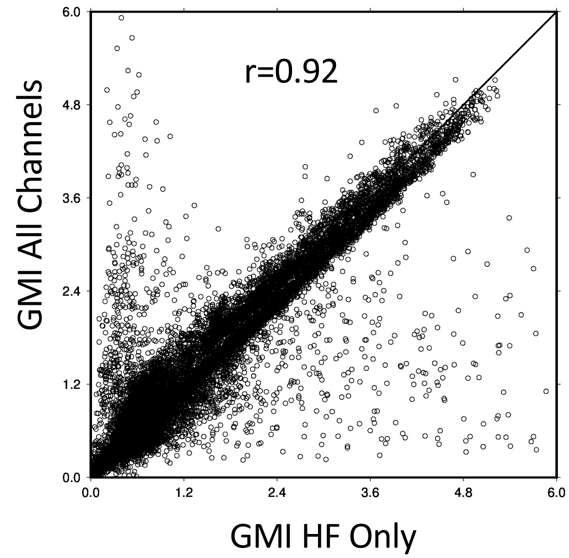


All vs High-Freq Channels Only



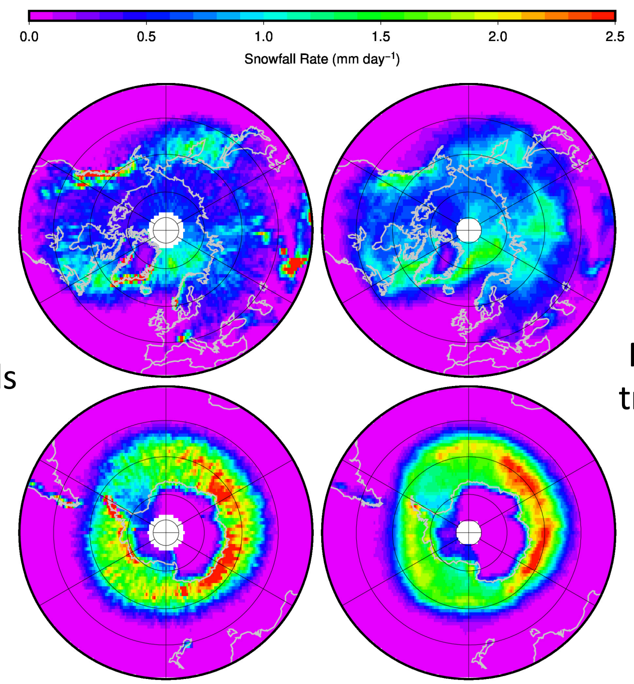
High-Freq Chs only
(89 – 183 GHz)

All but 10 GHz
(18 – 183 GHz)



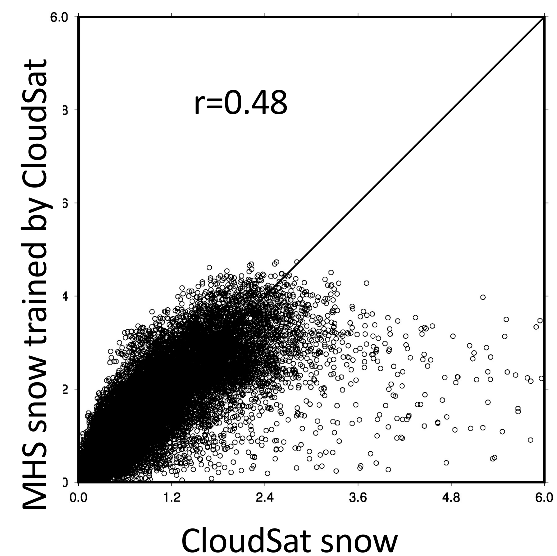
Snowfall Retrievals by MHS (89-183GHz) trained by CloudSat

CloudSat retrievals



MHS retreievals train by CloudSat

4 years averages

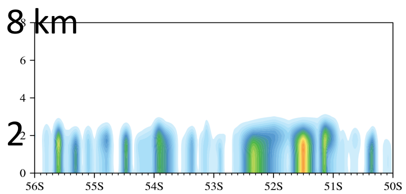


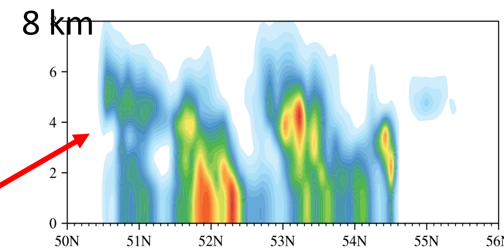
Over ocean, a more physically-based retrieval – Building 1D-Var optimized database

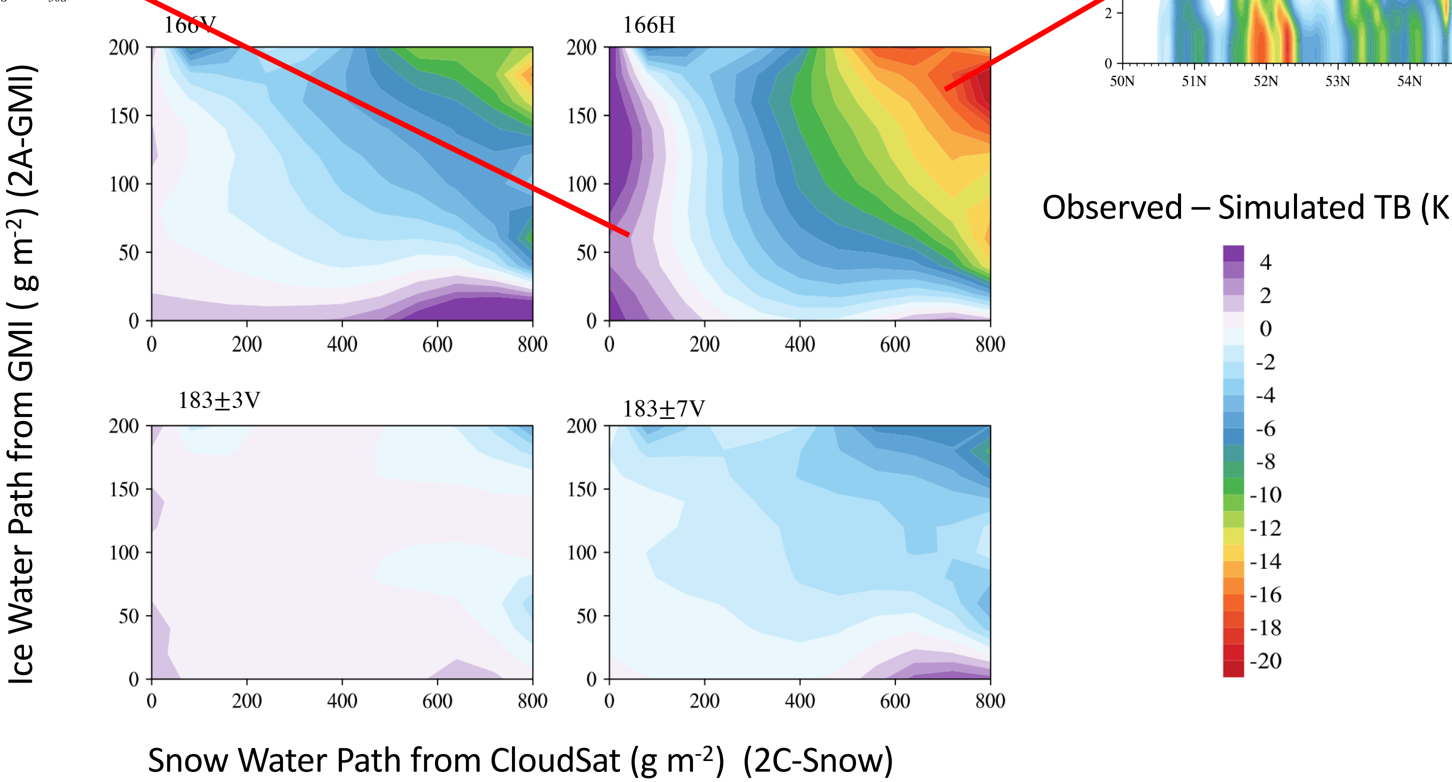
1D-Var Optimization for snow-TB database

- Over ocean, for GMI data, we are developing an a-priori database for Bayesian type snowfall retrievals, similar approach to rainfall retrievals.
- It starts with ”co-incident” CloudSat CPR snow water profiles, use 1D-Var to optimize the profiles to match coincident GMI TBs.
- Build a snow profile – TB database using all available CloudSat – GPM obs

Why need to optimize?





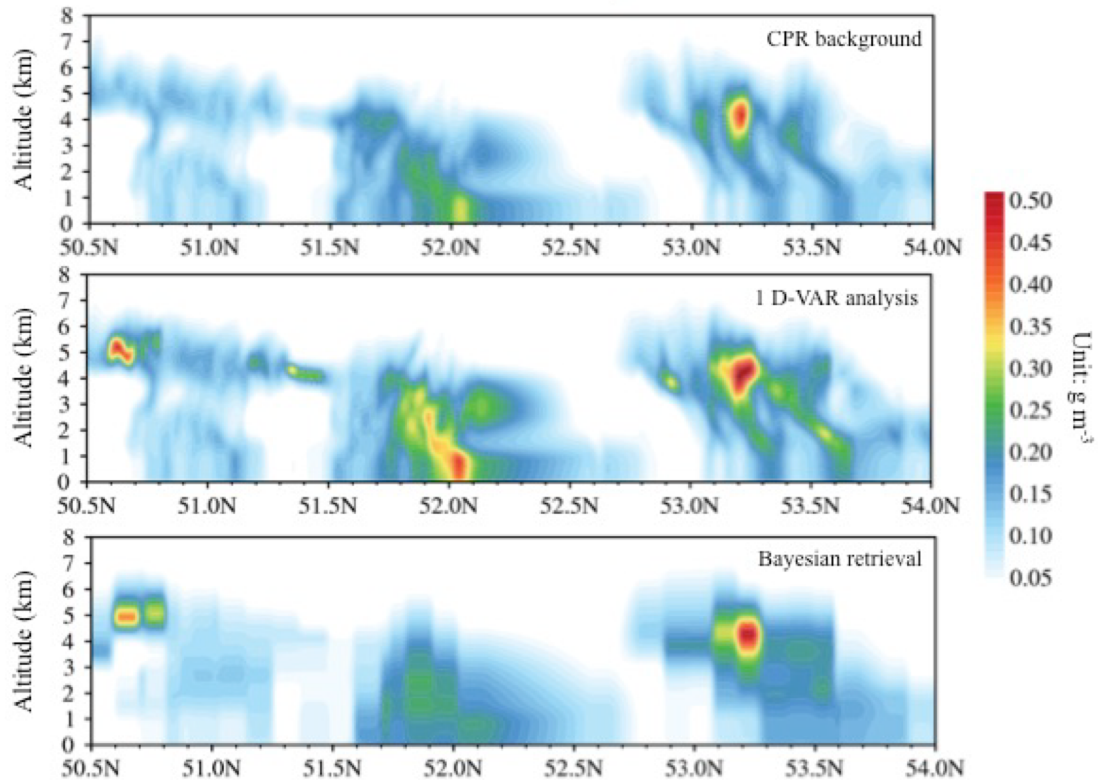


March 11, 2015 Case

Initial CloudSat-derived snow water profiles

After 1D-Var optimization to match GMI

Retrievals from GMI alone using the optimized database

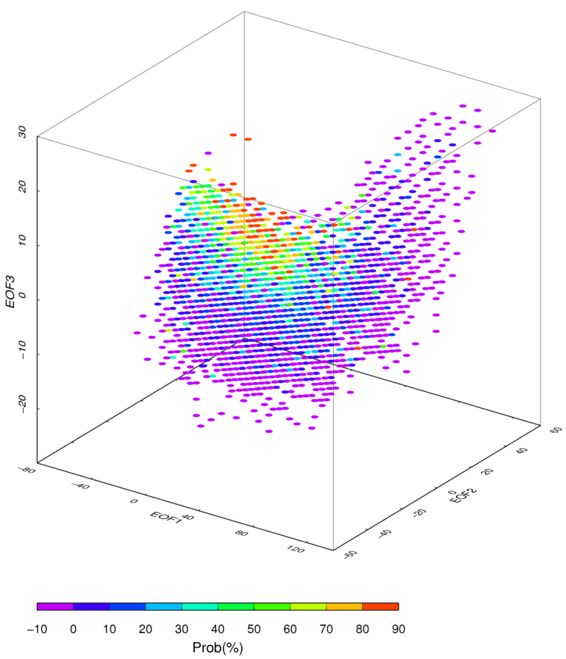


Conclusions

- Improving snow-rain separation scheme
  - Inclusion of lapse rate; equation version
- Enhancing nonspherical ice scattering tables
  - aggregates; bigger particles; interpretation triple-freq obs
- Developed a method to use CloudSat +GPM/DPR to guide passive microwave observations for snowfall retrievals
  - High-frequency channels (>85 GHz) is necessary (AMSR-E/2 does not seem to good), seems to be **sufficient**, for passive microwave snowfall retrievals
  - CloudSat + DPR training captures both light AND heavy snowfall
  - Able to retrieve snowfall using GMI, MHS, (SSMIS): Case studies, averages over US, average globally
- 1D-Var optimization to build snow-TB database for over-ocean snowfall retrievals
  - Find important factors that contribute to the difference between simulated and observed TBs

Backup Slides

Radar-Guided Passive Microwave Snowfall Algorithm (probability & snowfall rate)



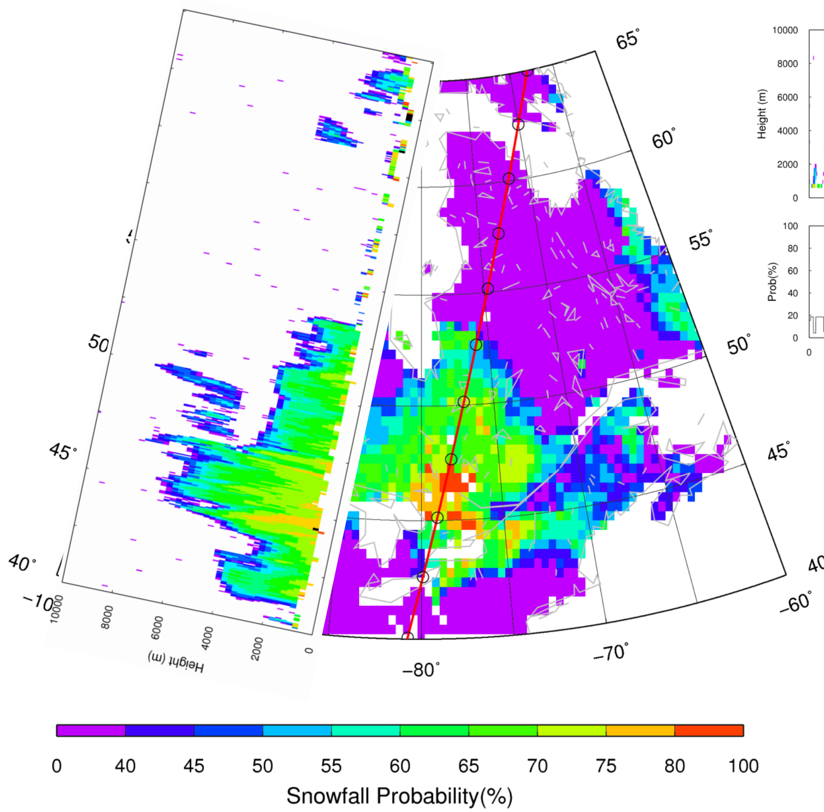
(Liu&Seo, 2013)

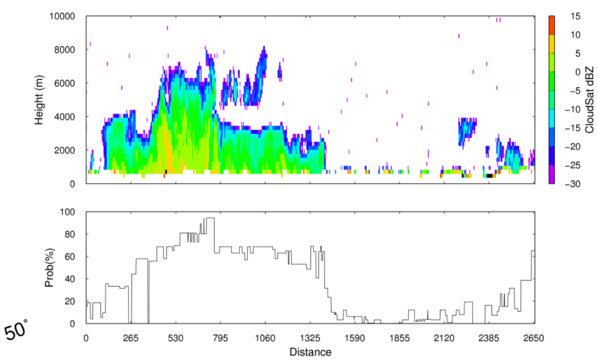
- EOF analysis to passive microwave data – for dimension reduction

- Lookup Table using collocated Radar-Radiometer data:
    - Project observed TBs to the first 3 PCs
    - In the 3-d EOF space, using passive microwave-CloudSat matchups, compute the probability of snowfall; Use a Z-S relation compute snowfall rate

- Lookup Table are separated by different surface/synoptic categories: currently 7

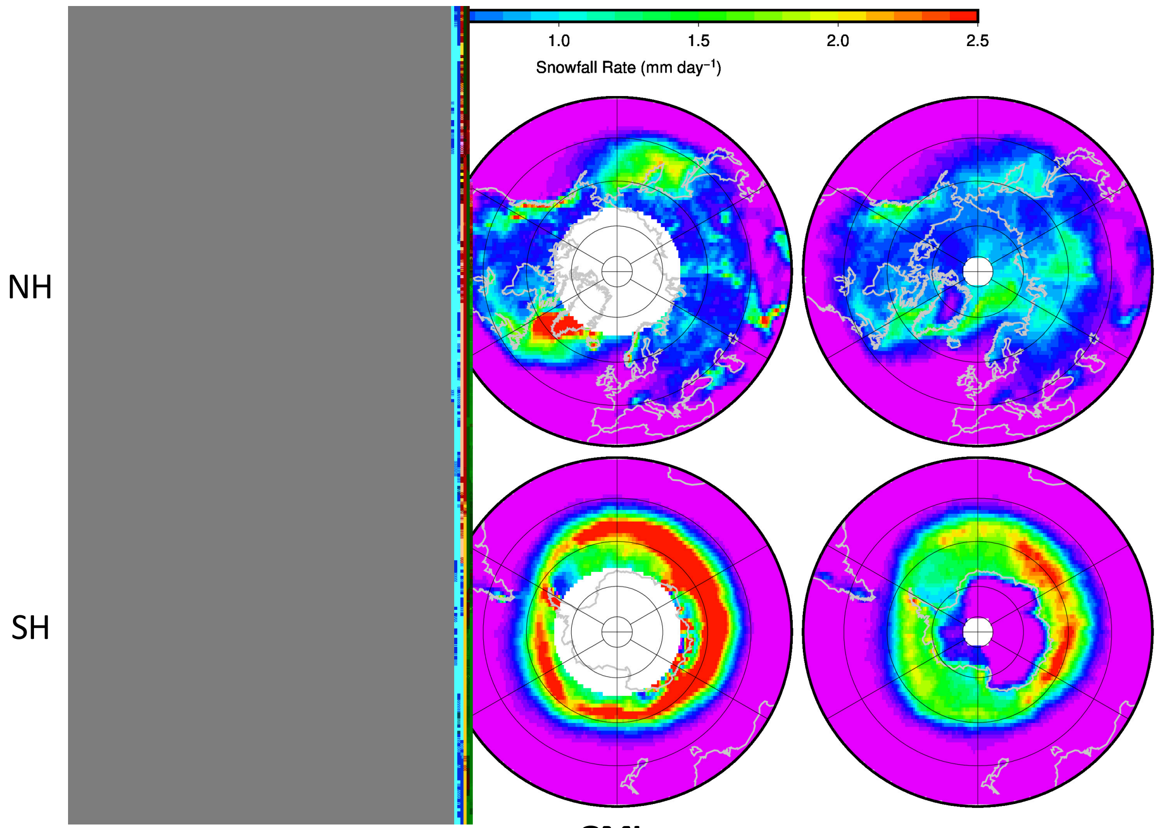
Apply to C3VP Case – 2007.1.22
CloudSat-trained MHS snowfall retrieval





The look-up-table approach successfully identified snowfall area

CloudSat-Guided Snowfall Retrievals - Global



CloudSat
4 years (2007-2010)

GMI
– trained by CloudSat&DPR
4 years (2014.03-2018.02)

MHS
– trained by CloudSat
4 years (2007-2010)